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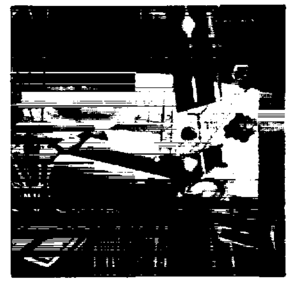
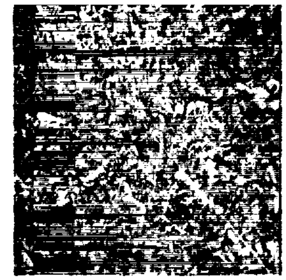
Centers for the Commercial Development of Space





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(NASA-PAM-525) CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE (NASA) 22 p CSCL 05A

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Grown some 200 miles above the Earth in a research laboratory called Spacelab 3, this crystal of mercuric iodide was part of an EG&G Energy Measurement's project funded by NASA and the Department of Energy to grow crystals of mercuric iodide from vapor.

Centers for the Commercial Development of Space

Editor
Susan E. Walker

This publication was produced by NASA Office of Commercial Programs, Public Affairs Office. The Centers for the Commercial Development of Space program serves as a cornerstone of NASA's activities to encourage and support the fullest commercial uses of space.

For further information on the NASA commercial programs, contact:
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Centers for the Commercial Development of Space

In 1985, NASA initiated an innovative new effort called Centers for the Commercial Development of Space (CCDS). The CCDS program was designed to increase private-sector interest and investment in commercial space-related activities, while encouraging U.S. economic leadership and stimulating advances in promising areas of research and development.

Today, this exemplary government program has emerged as the lifeblood of the agency's commercial space activities.

NASA's nationwide network of 16 CCDSs represents a unique example of how government, industry, and academic institutions can combine resources and talents to strengthen America's industrial competitiveness.

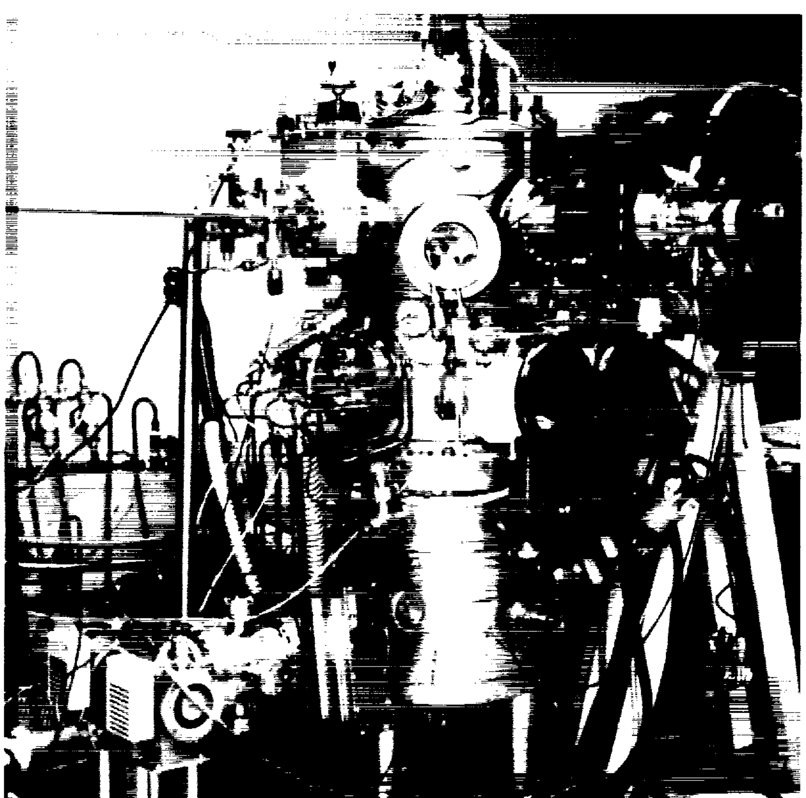
At the centers, space-based, high-technology research is conducted in a wide variety of areas. These areas range from remote sensing — which involves monitoring the Earth's surface to increase knowledge in areas such as crop and weather forecasting — to space-based materials processing in which the microgravity, high-vacuum environment of space is utilized to process unique, high-value products and learn more about Earth-based materials processing techniques.

By removing impediments, coordinating efforts, and encouraging private enterprise, the CCDS program helps move these emerging technologies from the laboratory to the marketplace with speed and efficiency.

In a relatively short time, these centers have made significant contributions toward encouraging and fostering greater private-sector investment and participation in commercial space ventures.

At present, CCDS affiliates include nearly half of the nation's 50 largest industrial corporations — some of which are affiliated with as many as 4 different centers.

As a new mechanism for increased NASA/industry cooperation, the CCDS program currently allows more than 125 industrial affiliates — many of them non-aerospace companies — and 51 university participants to explore the economic potential of space in this program where technical and financial risks are shared.



Space Vacuum Epitaxy Center (SVEC) research scientists built this unique high-vacuum chamber for high-temperature superconductor thin film growth. Groundbreaking research is being conducted in the chamber in collaboration with the Texas Center for Superconductivity, headed by former SVEC director Dr. Paul W. Chu.

Breaking New Ground

The accomplishments of CCDS participants include profound advances in a number of scientific fields and hundreds of Earth and space-based applications.

The 1986 superconductivity breakthrough by two scientists associated with NASA's CCDS program and a subsequent breakthrough by one of the same scientists, Nobel Prize nominee Dr. Paul W. Chu, of the Space Vacuum Epitaxy Center, University of Houston, received worldwide attention and marked historic scientific achievements, which promise significant social and economic implications.

Pioneering research into the use of space for the production of superior quality protein crystals is being performed under the leadership of the Center for Macromolecular

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Crystallography (CMC), University of Alabama-Birmingham.

Under this effort, major U.S. pharmaceutical companies — industrial affiliates of the CMC — are providing samples for space-based protein crystal growth. Acquiring high quality crystals from space could significantly advance research leading to the development of new drug treatments.

CMC experiments have flown on various Space Shuttle flights, including the post-Challenger missions of STS–26 and STS–29.

In 1989, another CCDS, The Consortium for Materials Development in Space (CMDS), University of Alabama-Huntsville led efforts to conduct materials processing research aboard the first commercially licensed U.S. rocket launch.

Space Services, Inc., a Houston-based firm, received a competitive commercial launch services contract from CMDS for the March 1989 launch of a materials science experiment payload aboard the firm's Starfire rocket.

Starfire's successful launch not only advanced research in materials processing, but also helped further federal efforts to foster growth of a strong and vigorous U.S. commercial launch industry.

Other collective CCDS accomplishments include: drop tube tower experiments, KC-135 flight experiments, Lear jet flights, and participation on Space Shuttle flights.

Program Structure

NASA's Office of Commercial Programs (OCP) selects, manages and provides annual funding of up to $1 million to the centers, placing a high priority on constructive leveraging of NASA grant investments and increasing reliance on industrial sponsorship.

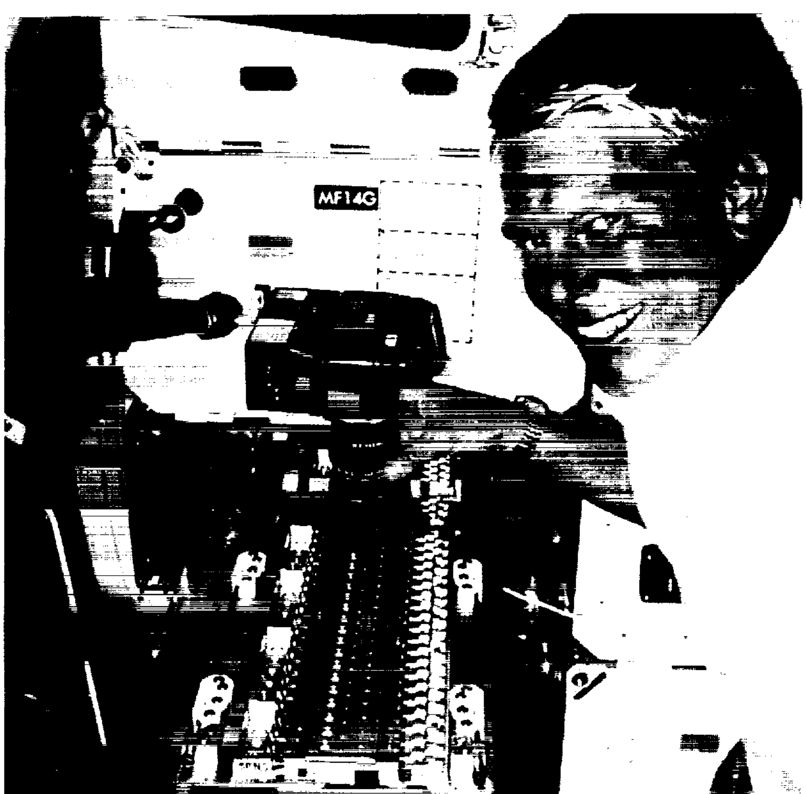
The centers receive additional financial and in-kind contributions from industrial affiliates which on the average exceed the NASA funding level. In 1986, less than one-fifth of the total funding for the first five CCDSs was derived from non-NASA sources. By 1989, non-NASA funding comprised nearly three-fourths of the total funding for the five centers.

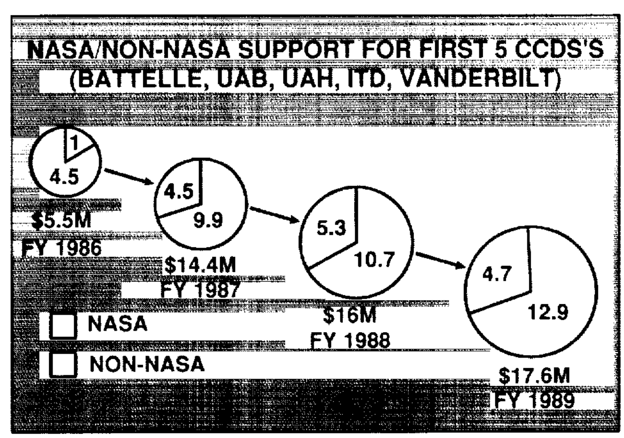
NASA also provides the centers with scientific and technical expertise, opportunities for cooperative activities, and other forms of continuing assistance.

Since initiation of the program, OCP's Commercial Development Division has issued three proposal solicitations listing various areas of promising space-related commercial R&D.

From the solicitations, 16 centers have been established in seven major research areas. Those areas include five CCDSs

Starfire 1, the first U.S. rocket licensed for commercial spaceflight, burst off Launch Complex 36 at White Sands Missile Range, New Mexico, at 8:40 a.m., MST, March 29, 1989, ushering in a new era of commercial rocket launches and evidencing how NASA funding, university talent, and industry ingenuity can combine to spawn new commercial enterprises.





This chart shows the percentage of the total funding for the first five Centers for the Commercial Development of Space derived from NASA and non-NASA sources from 1986–89.

Astronaut George "Pinky" Nelson activated and monitored the protein crystal experiments, sponsored by NASA and the Center for Macromolecular Crystallography, aboard Discovery on STS–26 in September 1988.

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dedicated to materials processing research, three conducting life science-related research, two in remote sensing, two committed to automation and robotics, one concentrating on space propulsion, one devoted to space structures and materials, and two focusing on space power research.

The centers are based at universities and research institutions across the country and are linked with at least one NASA field center.

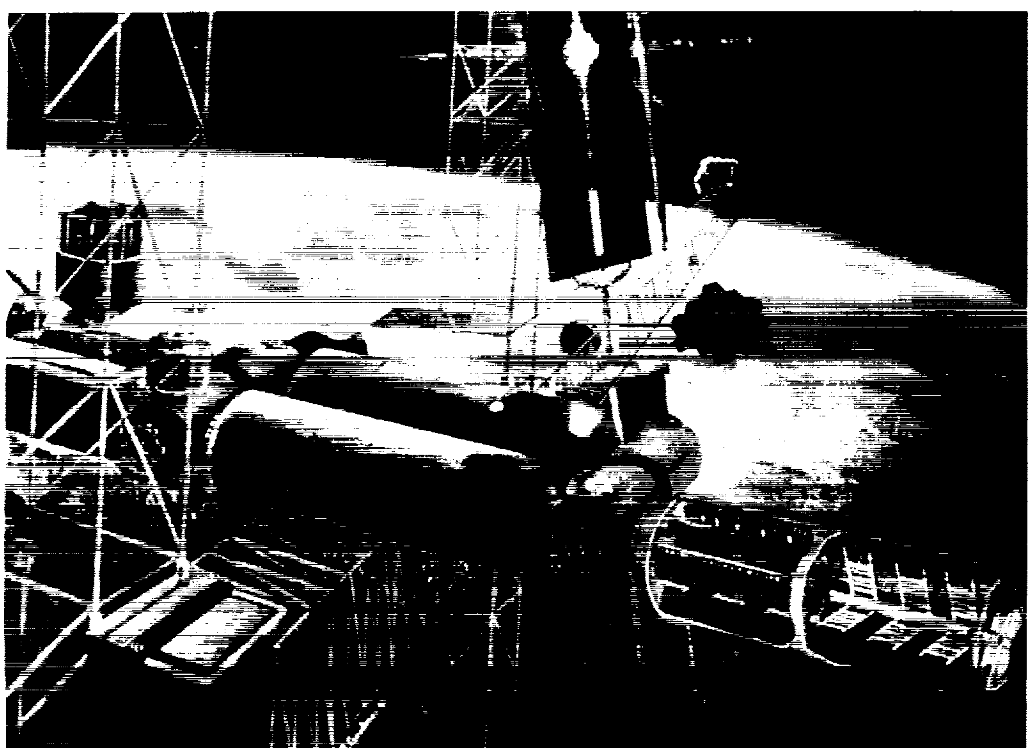
Future Focus

As an incubator for future commercial space industries, the CCDS program has facilitated a number of new commercial space ventures since its inception and supported a wide range of on-going efforts. In the future, it is anticipated that each center will lead to new Joint Endeavor Agreements between NASA and industry. These no-exchange-of-funds agreements are designed to encourage early space ventures and demonstrate the use of space technology to meet marketplace needs.

In addition, development of a new agreement mechanism to facilitate early space flight opportunities for CCDS participants is being finalized.

To date, some 46 Space Shuttle flight request forms have been submitted to OCP by the centers.

To accommodate the growing demand for CCDS-sponsored secondary Space Shuttle payloads, a CCDS payload selection/ranking process has been developed by OCP.



The Space Station Freedom, the next step in space exploration and the commercial development of space, will involve the participation and input of NASA's 16 Centers for the Commercial Development of Space (CCDS). The Wisconsin Center for Space Automation and Robotics (WCSAR) represents just one of the CCDSs working to develop technologies that will contribute to the success of the Space Station and future space goals. WCSAR's efforts to develop automated plant growth facilities for space are illustrated in an artist's concept of a plant growth unit attached to the Space Station.

Emphasis will also be placed on providing industry with other forms of opportunities for commercial space research, such as the CMDS-sponsored sounding rocket launch which was the first in a series of such launches planned.

The second of such launches will carry experiments sponsored by a number of CCDSs and is planned for the fall of 1989.

Efforts to ensure greater CCDS involvement in current and future commercial space activities will continue. A Management Working Group, comprising center directors, has been formed to provide NASA officials with increased CCDS input on commercial program activities.

An initiative is also underway to ensure strong CCDS involvement in the commercial aspects of the Space Station Freedom program. A team of members from each center will be formed to serve as designated CCDS Space Station planners and spokesmen.

The CCDS program has emerged as a critical tool toward increasing industry involvement in U.S. commercial space activities, encouraging and supporting new and ongoing commercial space ventures, as well as spawning research and development advancements which promise enormous social and economic benefits for all. This booklet was prepared by the Office of Commercial Programs to provide an introduction to each of these unique centers and their activities. □

For more information on NASA's CCDS program write:

CCDS Program Manager
NASA Headquarters
Commercial Development
Division/Code CC
Washington, DC 20546

Advanced Materials Center for the Commercial Development of Space

Formed in November 1985, the Advanced Materials Center for the Commercial Development of Space, located at Battelle Memorial Institute in Columbus, Ohio, conducts research into advanced materials including polymers, catalysts, electronic materials, metals, ceramics, and superconductors.

Commercial applications of these materials are selected for study in microgravity, with the objective of improving the characteristics of the commercial product, improving the process by which the product is made, or gaining additional information about the material, which could improve Earth-based processing. All programs selected for study are defined by industry partners.

Participants in the Battelle CCDS are supported by Lewis Research Center and Marshall Space Flight Center. Both contribute facilities, expertise, and flight development consultation. Center membership includes the following companies from the private sector:

- Amoco Chemical Company
- DuPont
- Hercules
- Master Builders, Inc.
- Rockwell International
- Teledyne Brown Engineering
- II–VI, Inc.

Other companies contributing to the center's operations are General Electric, Lockheed, and PPG, Inc.

University affiliates are engaged on a subcontracted basis to perform key aspects of the center's research activities. Affiliate members include the following:

- Akron University
- Case Western Reserve University
- Clarkson University
- Cleveland State University
- Ohio State University
- Washington State University
- Worcester Polytechnic Institute

The center is currently working in four major technology areas. These include catalysts, polymers, semiconductors, and rapid solidification of metals and ceramics, including superconductors.

In both the catalyst and polymer areas, a significant amount of the ground-based research has been completed and numerous short-time microgravity tests have been conducted. Current efforts are centered on preparing for space flight by developing hardware and modifying existing NASA hardware. Several flights aboard the Space Shuttle and in sounding rockets are planned beginning in 1989.

The center's semiconductor research is focused on the high-temperature crystal growth, by the float-zone method, of CdTe. While the pre-flight work is lengthy and difficult, this program is considered by industrial partners to be extremely important commercially.

The opportunity for deep undercooling and containerless processing that the microgravity environment provides is ideally suited for solidification studies. In this fourth research area, work is underway on ceramic superconductors, liquid phase immiscibles, and bearing materials. ☐

Further information on the Advanced Materials CCDS can be obtained by writing:

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Director
Advanced Materials CCDS
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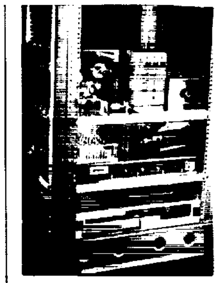
(614) 424–6376



This apparatus was flown on the Lear jet to produce the polymer composites.

The flight and science crew of a Battelle center project to produce polymeric composites in low gravity stand in front of the Lewis Research Center Lear jet used to fly the experiments.

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Center for Space Processing

An Ultra-high Temperature, Directional Solidification Furnace is used by the center in its exploration of the space processing of engineering materials.

In the unique microgravity environment of space, an almost limitless potential for significant advancements in Earth- and space-based materials processing exists. These promises of profound advances — ranging from creation of stronger metals to unique new materials — are being explored by the Vanderbilt Center for the Space Processing of Engineering Materials.

Established in 1985, the center is located on the Vanderbilt University campus in Nashville, Tennessee. Major research involves microgravity experimentation in containerless processing, directional solidification, casting, and cold welding. Studies are being conducted on four materials: metals, alloys, ceramics, and glasses.

By creating the methodology and technology needed to simulate processing of these four materials in a space environment, the Vanderbilt Center's efforts have greatly increased the scope of microgravity research.

The results of these efforts will be seen in the application of research to Earth-based manufacturing processes and will provide the basis for future commercial exploration of the space environment and resources.

Current center projects include: Directional Solidification of Aluminum Casting and Wrought Alloys; Deep Undercooling of Nickel and Iron Aluminides; Containerless Processing of Iridium and Ruthenium; Casting and Directional Solidification of Immiscible Alloy Systems; Containerless Processing of Refractory Alloys; and Solidification of Niobium/Titanium Alloys.

Each of these projects has a direct commercial connection to the manufacture of metals and materials with attributes for high-performance such as enhanced corrosion resistant properties, wear resistant properties, high temperature strength, oxidation and resistance.

Another unique project has been the design of a 30-meter drop tube to expand the center's facilities for simulating a microgravity environment for future experimentation. Funds have been pledged by NASA, corporate center members and Vanderbilt University to undertake the construction of this drop tube.

Experimentation has been conducted at Marshall Space Flight Center, Lewis Research Center and Oak Ridge National Laboratories. The center also works with subcontractors at the University of Florida/Gainesville, the University of Alabama/Tuscaloosa and with industrial partners at Engelhard, GTE, Lockheed, Boeing, Teledyne Brown, Teledyne Wah Chang, and the Cabot Corporation.

Based on the success of current microgravity projects, the Vanderbilt Center for Space Processing will continue to provide the American space program with the kind of profitable and practical results needed to fully involve corporate America in future space efforts. This partnership among industry, universities, and NASA can contribute to U.S. technological leadership and economic prosperity as the frontier of space is developed. □

For more information on this CCDS contact:

Center for Space Processing
Program coordinator
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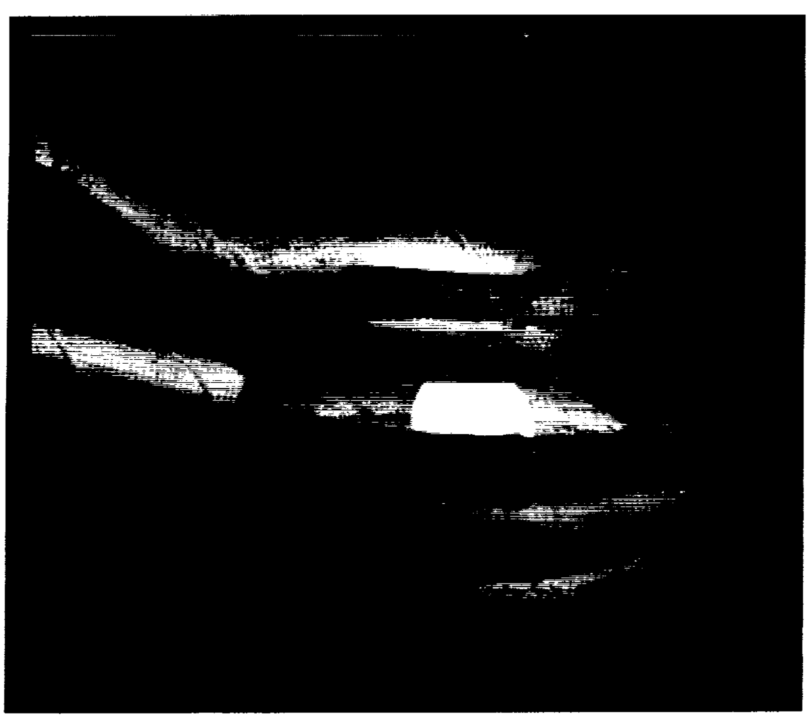
(615) 322-7047



A levitation-melted copper sample is shown.

Consortium for Materials Development in Space

The Consortium for Materials Development in Space, established at the University of Alabama in Huntsville (UAH) in 1985, focuses on investigations in space as a means to develop new materials and processes.

This approach covers: commercial materials development that benefits from the unique attributes of space; commercial applications of the physical chemistry that occurs at the surface of a new material, and how materials are transported to it; and prompt and frequent experiments and operations in space.

Current corporate partners are Boeing Aerospace, Deere & Company, Frontier Research, IBM's Almaden Research Center, McDonnell Douglas, Teledyne Brown Engineering, and Wyle Laboratories.

CMDS's prime NASA partner is its neighbor, Marshall Space Flight Center, although other NASA centers are strong supporters. UAH participates in the CMDS through its Schools of Science and Engineering and four university research centers.

The principal activities of the consortium are organized into several projects, each with at least one co-investigator from industry and a special university investigation team.

CMDS's most significant science accomplishment to date is a 1986 breakthrough in high-temperature superconductors. CMDS was a principal source of funding and talent for the development of the first materials that conduct electricity, without resistance, at temperatures "hotter" than liquid nitrogen, 77°K (–196°C).

The mixed-phase metal oxide developed by scientists at UAH demonstrated superconductivity at 93°K (–160°C) and spurred a global race to develop and manufacture devices based on these materials.

Several CMDS projects emphasize the development of materials with highly non-linear optical characteristics. These take the form of organic and inorganic crystals or thin films, which one day may be needed as components in future optical computers.

Surface coatings for a variety of applications constitute another line of materials development. Atomic oxygen can erode coatings that must maintain constant properties on spacecraft surfaces for extended periods.

Understanding materials produced by electrodeposition is another issue addressed by the CMDS in a project sponsored by McDonnell Douglas. Several polymer projects — such as gravitational effects on demixing of polymers, formation of foams in microgravity, and improved materials for radiation detectors — are included in the CMDS program. Powdered metal sintering and related processes under microgravity conditions are further subjects of development.

Research has been carried out on the ground and aboard NASA's KC-135 low-gravity aircraft as preparation for space flight aboard suborbital rocket and orbiting carriers.

In 1987, CMDS began working towards a sounding rocket flight. UAH selected Space Services Inc. to provide a launch in March 1989 aboard a Starfire 1 launch vehicle. This successful endeavor was the first U.S. commercial licensed launch and signified the beginning of a new era of U.S. commercial launches.

The Consort 1 flight carried six experiment devices supporting a wide range of investigations.

Future CMDS flight experiments will fly aboard suborbital rockets, Getway Specials, and the U.S. Microgravity Laboratories. □

For more information on the Consortium for Materials Development in Space contact:

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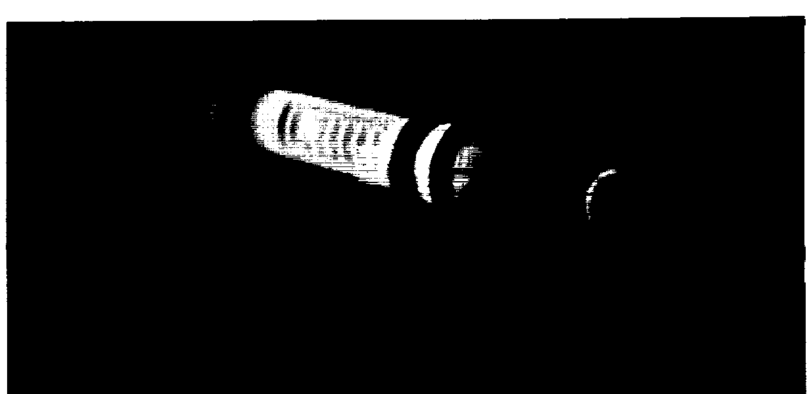
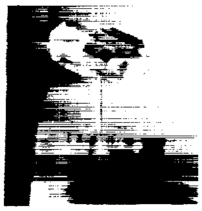
Consortium for Materials
Development in Space
University of Alabama in
Huntsville
Huntsville, AL 35899
(205) 895–6620

Liquid nitrogen bubbling in a plastic cup demonstrates how "hot" superconductivity has become following a development by Marshall Space Flight Center and the Consortium for Materials Development in Space (CMDS) officials. The mixed-phase metal oxide retains its strong magnetic field at -160°C. The suspension effect shown here, caused by a magnetic field trapped in the sample, was discovered by CMDS and Marshall officials when silver oxide was added to the CMDS recipe for superconductors.



A prototype of a physical vapor transport furnace supplied to the center by Boeing for ground-based testing is illuminated by the glow from its own heat.

Center for Commercial Crystal Growth in Space



This doped triglycine sulfate crystal was grown in 1 g.

Clarkson University's Center for Commercial Crystal Growth was established in September 1986. This national consortium of industry, universities, and national laboratories is based at Clarkson University, Potsdam, New York.

The center's primary goal is development of commercial crystal growth in space, with emphasis on growth of single crystals of higher perfection than can be grown on Earth. Applications of this venture include electronics, optical systems, detectors, and separations.

The transparent furnace shown was developed by Boeing to enable scientists to view crystals during growth in space.

Primary corporate sponsors of the consortium are Boeing Aerospace Corporation, Grumman Corporation, EDO Barnes Engineering, and the Westinghouse R&D Center. A host of other companies, both small and large, contribute to center activities.

University researchers include Alabama A&M University, the University of Florida at Gainesville, the National Institute of Standards and Technology, Rensselaer Polytechnic Institute, and Worcester Polytechnic Institute. Marshall Space Flight Center also provides assistance to the center.

Research is performed by three teams: Melt Growth, Vapor Growth, and Solution Growth. The National Institute of Standards and Technology (NIST) participates in each of these teams. NIST utilizes the National Synchrotron Light Source at Brookhaven National Laboratory to characterize crystals by high-resolution X-ray topography.

Primary participants in the Melt Growth Team are Clarkson University, the University of Florida, Grumman, and the II–VI Corporation. This team is working on growth of cadmium telluride crystals by the Bridgman-Stockbarger technique and growth of gallium arsenide crystals by the liquid encapsulated molten zone technique.

These crystals are used in producing more resilient integrated circuits and infrared detectors. Potential applications include faster computers and more detailed infrared images.

Vapor Growth Team participants include Rensselaer Polytechnic Institute, Boeing, and Westinghouse. The Vapor Growth team is working on growth of cadmium telluride and mercury halide crystals by vapor transport techniques. Potential applications include devices for detecting high-energy particles such as nuclear radiation and cosmic rays.

Participants in the Solution Growth Team are Alabama A&M University, Worcester Polytechnic Institute, and Barnes Engineering. The Solution Growth Team is working on crystal growth of triglycine sulfate, L-alanine phosphate and zeolites.

Potential applications include optical computers, devices used to change the frequency or "color" of laser light, room temperature infrared detectors, catalysts for the petro-chemical industry, and separation of chemicals produced by biotechnology and radiation waste storage.

Each of the above teams is performing ground-based experiments and planning flight experiments.

While the ground-based work is aimed primarily at preparing for flight experiments, it is producing results useful now for commercial crystal growth on Earth. □

For more information on the Center for Commercial Crystal Growth in Space contact:

Bill Wilcox
Center for Commercial Crystal Growth in Space
Clarkson University
Potsdam, NY 13676
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Space Vacuum Epitaxy Center

The Space Vacuum Epitaxy Center (SVEC) — a major research consortium based at the University of Houston — is developing new techniques to use the ultra-vacuum of space for materials processing.

Established by NASA in 1986, this Center for the Commercial Development of Space is located in the Houston Science Center complex.

Research facilities include an Epitaxial Thin Film Facility with Class 10, Class 1000, and Class 10,000 clean rooms, Thin Film Superconductor Laboratory, and Analysis Laboratory.

Center participants include: AT&T Bell Labs, Murray Hill, New Jersey; Electro-Optek, Torrance, California; Instruments S.A., Inc., Edison, New Jersey; Perkin-Elmer, Eden Prairie, Minnesota; Rockwell International, Thousand Oaks, California; U.S. Army Research Division, Watertown, Massachusetts; University of Illinois, Urbana, Illinois.

NASA field centers assisting SVEC include Johnson Space Center, Houston, Texas, and Marshall Space Flight Center, Huntsville, Alabama.

The center's primary research focus is aimed at exploring epitaxial thin film growth and materials purification in the ultra-vacuum of space.

An ultra-high vacuum allows for the controlled deposition of unique thin films by epitaxial growth. Researchers consider vacuum epitaxy to be the most powerful technique available for synthesizing new thin film electronic, superconducting, and magnetic materials and devices.

Unique epitaxial procedures developed at SVEC can be used for production of these new products, which possess enhanced qualities.

In addition to providing an excellent environment for epitaxial thin film growth, space allows for the purification of materials needed in the production of high-quality semiconductor, superconductor, and magnetic materials.

SVEC's future efforts will concentrate on adapting Molecular Beam Epitaxy and Chemical Beam Epitaxy (MBE and CBE) technologies to the space ultra-vaccum environment and development of semiconductor thin film materials and devices.

A major emphasis is also being placed on helping to increase access to, and utilization of the space ultra-vacuum. This ultra-vacuum can be achieved by deployment of a Wake Shield Facility (WSF) in a low-Earth orbit. SVEC and Space Industries, Inc., of Houston, are jointly developing the flight hardware for a Shuttle-deployable WSF. Researchers expect the disk-shaped wake shield to produce an ultra-vacuum in the order of 10^{-14} torr in its wake. □

For more information on this CCDS contact:

Space Vacuum Epitaxy Center
Attn: Dr. Alex Ignatiev,
Director
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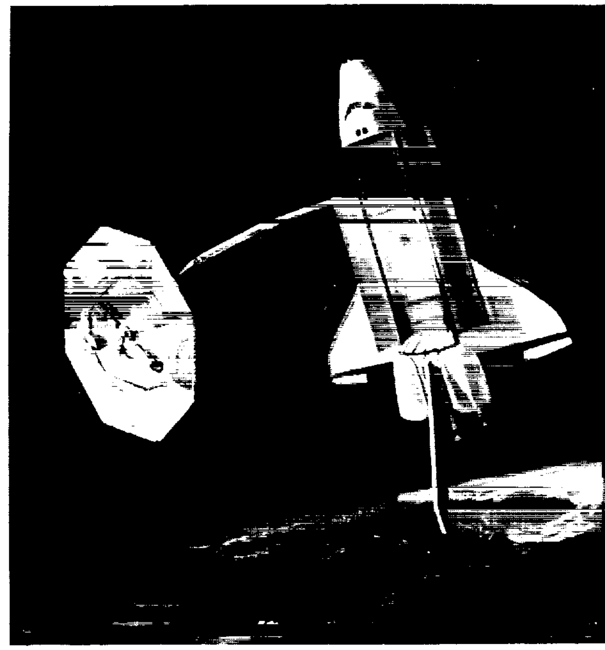
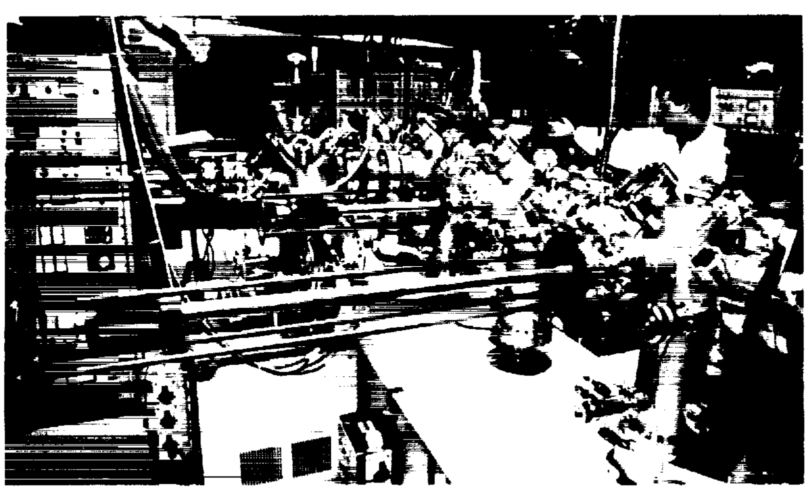
Houston, TX 77204–5507
(713) 747–3701



Operating a wake shield in space can create a higher quality environment for the production of thin film materials than anything achievable on Earth. Deployed by the Space Transportation System in a low-Earth orbit, the shield pushes aside stray atoms and molecules to create an ultra-vacuum in its wake.



The Space Vacuum Epitaxy Center houses a unique Molecular Beam/Chemical Beam Epitaxy System for thin film semiconductor growth, which is shown being operated by a research scientist.

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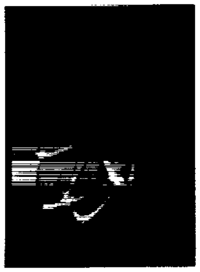
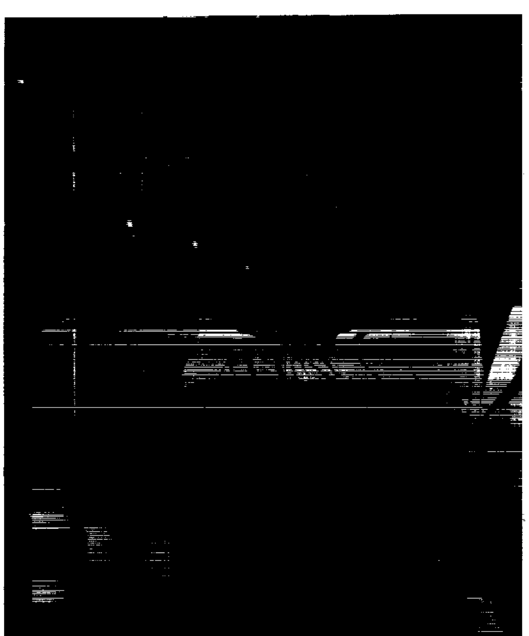
Center for Macromolecular Crystallography



Protein crystal growth experiments sponsored by NASA and the Center for Macromolecular Crystallography were flown on STS–26. The experiments included a sample of the enzyme isocitrate lyase for fungicides — a crystal of which is shown. Better understanding of this enzyme could lead to more potent fungicides to treat serious crop diseases such as rice blast.



Dr. Thomas Krenitsky of Burroughs Wellcome, an industrial affiliate of the Center for Macromolecular Crystallography (CMC), purifies a potential inhibitor of the protein reverse transcriptase. Burroughs Wellcome provided a sample of the protein — a proven target for AIDS drug development — as part of the NASA/CMC-sponsored protein crystal growth experiment package flown on STS–26.

The Center for Macromolecular Crystallography (CMC), a unit of the University of Alabama at Birmingham, Alabama, was among the first five of NASA's Centers for Commercial Development of Space established in 1985.

The center's research programs cover all major areas of macromolecular crystallography. Crystallography is the only technique available for determining the three-dimensional atomic arrangements within complicated biological macromolecules. By bombarding crystals of a macromolecule with X-rays, diffraction patterns are produced that permit determination of the molecule's complete architecture. The resulting structural information is essential for understanding the fundamental structure/function relationships that regulate biological systems.

Macromolecular crystallography is a powerful research tool in the pharmaceutical, chemical, and biotechnology industries for drug design and protein engineering. Recent results from Space Shuttle experiments demonstrate that improved crystals of biological macromolecules can be obtained using the unique microgravity environment of space.

The center is involved in development of new techniques for protein crystal growth on Earth and in space; structural studies of biological macromolecules using protein crystallography; applications of protein crystallography in drug design and protein engineering; and development of improved hardware and software systems for assisting in various experimental aspects of macromolecular crystallography.

CMC facilities and personnel are available to industrial guest investigators, which currently include scientists from BioCryst, Burroughs-Wellcome, Dow, Dupont, Eli Lilly, Genentech, Eastman Kodak, Merck, Procter & Gamble, Schering Plough, Smith Kline-Beckman, and Upjohn. In addition, the center has collaborative microgravity research programs with other universities and government laboratories, including the Marshall Space Flight Center, University of Alabama in Huntsville, University of North Carolina, University of Texas, University of Pennsylvania, Brookhaven National Laboratory, University of Washington, University of Chicago, Georgia Institute of Technology, and the Naval Research Laboratory.

CMC-sponsored protein crystal growth experiments flew on the first post-Challenger mission of STS–26 in the fall of 1988, and an additional set of experiments was flown on STS–29 in early 1989.

Recent major achievements of the center include determination of the three-dimensional structure of human purine nucleoside phosphorylase, an enzyme that is a target for the design of drugs to be used in cancer and AIDS chemotherapy, suppression of the immune system in tissue transplants, and for treatment of autoimmune diseases such as rheumatoid arthritis. The structural results for this protein have already led to the development of several potent new inhibitors of the enzyme. Results from the protein crystal growth experiments on STS–26 and STS–29 provided clear evidence that microgravity can be used effectively to produce improved protein crystals for structural studies. Advanced hardware now being developed through the center will allow industrial guest investigators to be involved in forefront applications of microgravity to protein crystal growth on future Shuttle flights and ultimately on the Space Station.□

For further information on the Center for Macromolecular Crystallography contact:

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Bioserve Space Technologies

Bioserve Space Technologies Center for the Commercial Development of Space was established at the University of Colorado, Boulder, Colorado in October 1987. Currently consisting of nearly 30 business, foundation, government, and academic participants, Bioserve specializes in space-borne biomedical and agricultural research.

Center participants include Fortune 500 companies with varied life sciences or aerospace interests, as well as smaller entrepreneurial businesses.

The center receives its prime technical support from Ames Research Center. Bioserve also receives technical support from Johnson Space Center, Marshall Space Flight Center, and Kennedy Space Center.

In addition, Bioserve maintains a strong relationship with Kansas State University's Division of Biology, and is currently forging ties with three other mid-American universities.

As many as 50 projects are underway at various Bioserve facilities. These activities can be grouped into one of four categories:

1. Bioproducts/Bioprocessing: Focuses on forming and manipulating biomaterials in the microgravity environment.

Advanced biocompatible materials formed from the self assembly and polymerization of proteins and other macromolecules may be used for artificial skin, tendons, blood vessels, and cornea; and for advanced membrane technologies.

Payload systems executive and former astronaut Byron Lichtenberg looks on as University of Colorado student researchers and NASA astronaut Marsha Ivins ham it up for the camera at the conclusion of a three-day series of microgravity KC-135 flights.

Recently, Bioserve performed pioneering experiments on one of NASA's KC-135 zero-gravity research aircraft.

2. Biomedical Isomorphisms: Occur as numerous degenerative changes in astronauts exposed to the reduced gravity and radiation environments of space.

Bioserve is exploring the possibility that these changes may be used as important models of similar degenerative disorders that occur on Earth. For example, the bone material loss that affects astronauts in space is being used to model osteoporosis processes that occur on Earth.

3. Controlled Ecological Life-support Systems (CELSS): Involves the investigation of biologically based technologies that will permit efficient, effective, simple waste management, water reclamation, and production of food and oxygen in space.

Many of these technologies may also have relatively immediate applications here on Earth in water reclamation, waste management, and agricultural arenas.

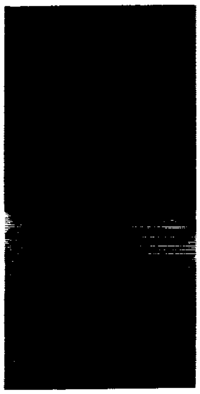
A pilot microorganism-based bioreactor is being constructed and will be operational by the first quarter of 1989. This system is being designed to convert waste into useful products and aid in purifying water. Additionally, Bioserve researchers are constructing a "Salad Machine" — a plant growth module that will be capable of supplying fresh vegetables to astronauts in long-duration space missions.

4. Hardware Development in Support of Bioserve Projects: Being conducted to permit maximum utilization of existing, flight-qualified equipment, and develop new hardware. □

Parties interested in learning more about Bioserve are invited to contact:

Bioserve Space Technologies
University of Colorado,
Campus Box 429,
Boulder, CO 80309
Attn: John Berryman, Associate Director, External Affairs
(303) 492–1005

Center for Cell Research



Growth hormone secretion from individual pituitary gland cells can be examined clearly through the use of the cell blot technique.

The orange-colored blots shown above illustrate acid production by cultured osteoclasts, the cellular agents of bone resorption.

The Center for Cell Research (CCR), established in 1987, is a biologically oriented CCDS. Its main goals are definition of the fundamental mechanisms of mammalian cell function on Earth and in space and commercialization of the findings in cooperation with business and industry.

The CCR is a national science center based at Pennsylvania State University (PSU). The current roster of 31 scientists come from the colleges of Science, Chemical Engineering, Agriculture, and Health and Human Development at PSU, Arizona State University, Columbia University, Jefferson Medical College, Mayo Clinic, Nemours Foundation, Tulane University, UCLA, University of Wisconsin, as well as from the Ames Research Center and Johnson Space Center.

These scientists (who specialize in cell secretion, differentiation, energetics, biochemistry, and proliferation; biomechanics; shear effects; and cell and molecular separations) were selected because of contributions they can make to the three major projects of the center — the musculoskeletal system (bone and hematopoiesis), the light/endocrine/immune axis, and bioprocessing. A state-of-the-art core cell analysis and separation facility supports their efforts (Fig. 1).

This basic research relates to commercial concerns — aging, anemia, bioprocessing, cell secretion, diabetes, drug delivery, hormone production, immune function, light effects, muscle atrophy, osteoporosis, transfected cells, etc.

For example, Lunar Radiation Corporation, Wisconsin, is attempting to miniaturize its dual-energy bone densitometer in order to monitor bone density of personnel and animals in space and on earth. Corabi International Telemetrics, Maryland, is marketing a telepathology instrument for long distance transmission and control of microscope images and developing it for use on Freedom Space Station. Genentech, California, has contracted with the CCR to perform animal experiments in microgravity.

The CCR will assist them by: (1) participating in the R&D; (2) doing ground-based testing; (3) making it possible for them to test in space; and (4) fostering collaboration between them and other CCR-affiliated companies.

Other client projects relate to several aspects of bioprocessing in space, microgravity-caused aberrations in mammals which resemble diseases on Earth, and visible light-caused changes in immune response. □

For more information on the Center for Cell Research contact:

Dr. Sylvia Stein
Executive Director
416 Wartik Laboratory
Penn State University
University Park, PA 16802
(814) 865-2410

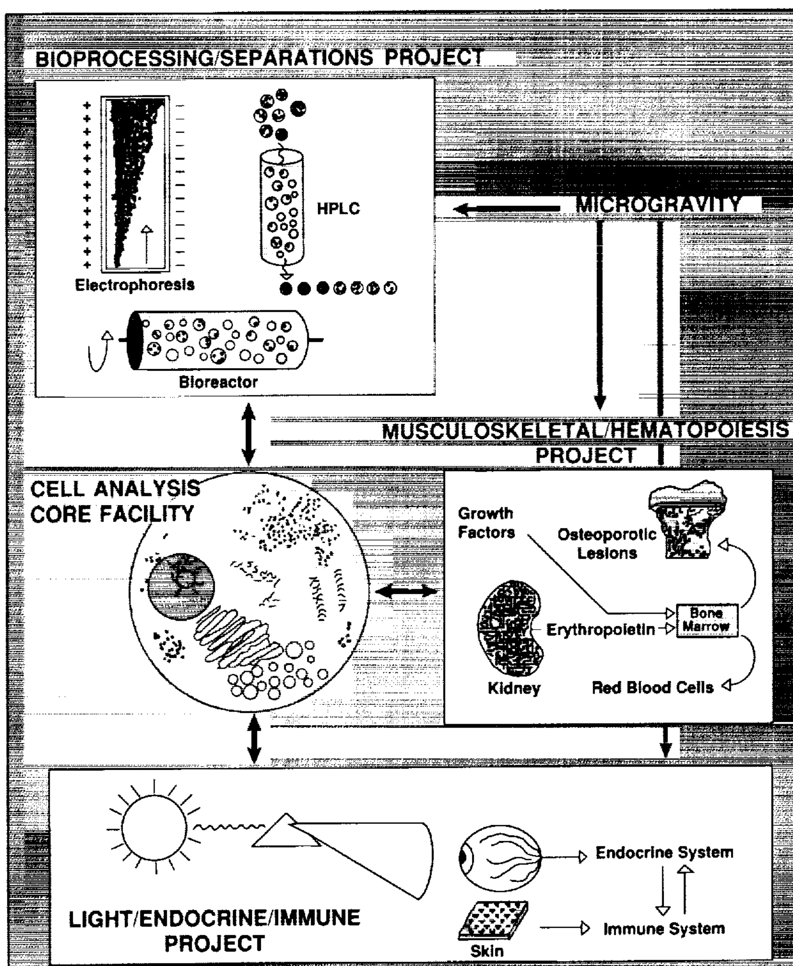


Figure 1

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Center for Mapping

The NASA-sponsored Center for the Commercial Development of Space (CCDS): Real-Time Satellite Mapping at The Ohio State University was funded in 1986 and is a part of the Center for Mapping. This center aims to develop methods of gathering information from satellites, correlating that information with existing data, and applying advanced mapping techniques in the commercial market place in "real-time."

Center industrial partners include Battelle Memorial Institute, Corrugated Plastic Tubing Association, Digital Equipment Corporation, Earth Satellite Corporation, Gas Research Institute, Intergraph, Environmental Systems Research Institute, The Nature Conservancy, Ohio Department of Natural Resources, Synercom Technology, Inc., Tektronix, Inc., Trimble Navigation, Ltd.

Corporate/government affiliates include Agriculture Research Service, American President Lines, Coastal Science & Engineering, Inc., Conservation Technology Information Center, ERDAS, Inc., GeoSpectra, Inc., Goddard Space Flight Center, Intergraph Corporation, John Hopkins Applied Physics Laboratory, Metropolitan Parks Commission of Columbus & Franklin County, Micronautics, Inc., Mid-Ohio Regional Planning Commission, Muskingum Watershed Conservancy, National Ocean Service/NOAA, Ohio Chapter of Land Improvement Contractors of America, Stilson Associates, USDA-ARS Beltsville Agricultural Center, USDA-ARS Soil Drainage Research Unit, USDOT Maritime Administration, and U.S. Geological Survey.

The research and demonstration projects conducted at this CCDS are primarily driven by commercial needs in land, water, and farm management, in energy and power production, digital mapping, information systems, and disaster assessment. Consequently, research efforts have ranged from forecasting storm surge levels to analyzing the impact of drought conditions in the Midwest, from anticipating satellite orbits to monitoring gas leaks, and from predicting the effects of erosion to tracking ocean currents.

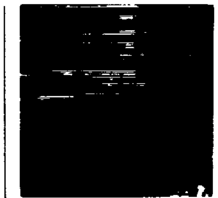
Two of the center's most successful projects are "Feature Extraction From Aerial Photographs and Interpreting Raster-Scanned Map Data" and "Extracting Three-Dimensional Information from Aerial Imagery and Determining Elevation Models." These projects seek to provide an automatic means of tapping a rich source of information, namely maps. In these projects "expert systems" or artificial intelligence techniques are used to solve difficult problems in automated map interpretation and image analysis. The overall goal of these two projects is to produce and update maps from satellite and aerial imagery faster and more reliably.

Because of the ground-breaking nature of this research and the unique utilization of photogrammetry and computer vision, two companies, Digital Equipment Corporation (DEC) and Intergraph Corporation, became interested in the projects.

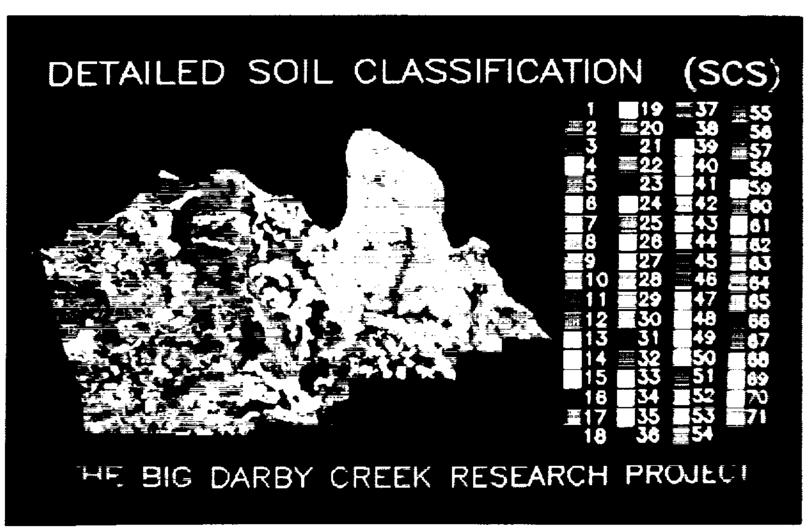
With the new technology and expertise brought to the project by DEC and Intergraph, future research efforts will focus on the construction, refinement, and segmentation of object space descriptions from satellite and aerial stereo image pairs and on feature extraction from both image and object space descriptions. □

For further information on the Center for Mapping contact:

Center for Mapping
The Ohio State University
1958 Neil Avenue
Columbus, OH 43210–1247
(614) 292–6642



The Big Darby Creek Watershed area shown in this photo is the focus of one of the center's major research projects.



This computer-generated soil classification map shows the varying compositions found in soil near the Big Darby Creek Watershed and illustrates how technology being developed by the center can be used to provide wide range of information.

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Space Remote Sensing Center

The Space Remote Sensing Center develops specific applications of remote sensing for diverse problems that can be solved through the use of this technology.

The Space Remote Sensing Center (SRSC) is developing commercial applications of satellite and airborne remote sensing, image processing, and geographic information systems. As a division of the Institute for Technology Development, Inc., SRSC has established a close relationship with numerous universities, private organizations, and NASA's Science and Technology Laboratory, located at the Stennis Space Center. Through these associations, SRSC is finding ways to improve the operational productivity and efficiency of those involved in land use planning and resource management.

The applications development program at SRSC is creating advanced techniques for agricultural crop monitoring, forest mensuration, environmental assessment, facilities monitoring, and land use planning. Economic benefits are gained directly from improved operational planning, which can lead to lower project cost.

In agriculture, SRSC is developing image processing techniques and computer models to assess vigor and yield for several crops. Diverse activities involving Hutson Fertilizer Company, agricultural banks, Maricopa Agricultural Center, Montana State University, and Purdue University have resulted in several applications with commercial promise. One product is a crop variability map derived from remotely sensed data. Farmers can use the map to reduce fertilizer costs by fertilizing each soil unit according to the soil's potential to grow a crop. Montana farmers working with this technology have saved between $7 and $11 per acre.

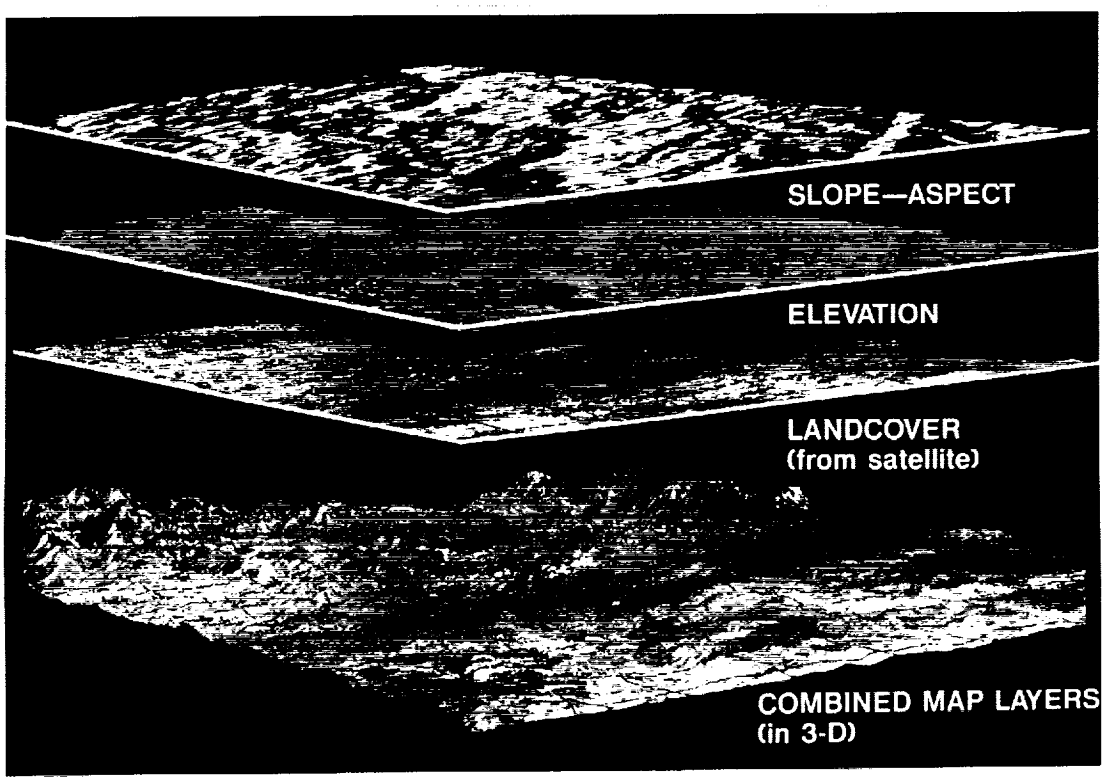
The forestry industry has also benefited from projects that SRSC has conducted involving large land-owning companies in assessing the commercial application of remote sensing for forest mensuration.

SRSC has been designated as the official support center for the U.S. Army Corps of Engineers Construction Engineering Research Laboratory's software package called GRASS (geographic resources analysis support system). The geographic information and image processing system has been recently ported to the Apple Macintosh II™ personal computer through SRSC's Apple Developer partnership. This has enabled many potential users of remote sensing and geographic information to access this data on a low-cost system.

Through these efforts, SRSC will continue to explore and develop applications of remote sensing to benefit the private sector. □

For more information on the Space Remote Sensing Center contact:

Director
ITD Space Remote Sensing Center
Building 1103, Suite 118
Stennis Space Center, MS 39529
(601) 688–2509



Creating a database with multiple data layers is important in managing commercial applications of remote sensing technology. This geographic information system image display shows how data layers can be combined to produce three-dimensional perspective views containing information from each layer.

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Wisconsin Center for Space Automation and Robotics

Automation and robotic technologies will be essential to the success of planned future space missions. To meet technology needs in this area, advanced capabilities, far beyond those currently available, will be required.

The Wisconsin Center for Space Automation and Robotics (WCSAR) is working to meet this challenge. Established at the University of Wisconsin-Madison, in September 1986, WCSAR's research in this innovative field is expected to produce a wide range of terrestrial spin-off applications.

The center's three major research areas include Astrobotics™, Astroculture™, and Astrofuel™.

In Astrobotics™, WCSAR is working to create robotic technologies capable of enhancing mankind's ability to live, travel, and explore in space. Robotic technology will be especially useful for accomplishing tasks in hazardous environments and those areas not easily accessible to humans. As an extension of the astronaut, this technology will be used to assist in performing a variety of complicated and routine tasks outside the spacecraft.

In Astroculture™, WCSAR is working to develop automated plant growth facilities for space. These galactic gardens will provide a plentiful source of oxygen and food, remove carbon dioxide, and purify water for long-duration and permanently manned space operations. In addition, plants will enhance the aesthetic quality of life in a space colony.

Astrofuel™ involves the mining and processing of Helium–3, an extremely valuable source of safe, clean, reliable fusion fuel. Identified as a component of the lunar regolith, the amount of Helium–3 on the Moon is estimated to be the energy equivalent of ten times that of the Earth's remaining fossil fuels. Successful recovery and transport of Helium–3 back to Earth may solve our energy needs for centuries to come.

WCSAR conducts research in laboratory facilities throughout the University of Wisconsin-Madison campus. Talent is drawn from university faculty and staff in engineering, agriculture, medicine, and the physical sciences, together with industrial consortium members.

The Lyndon B. Johnson Space Center serves as WCSAR's main NASA field center. Other NASA field centers, including Kennedy Space Center, Ames Research Center, Lewis Research Center, and Goddard Space Flight Center are also involved in cooperative activities with the WCSAR program.

WCSAR's industrial participants are Astronautics Corporation of America, Automated Agriculture, Inc., Deere & Co., McDonnell Douglas Astronautics Corporation, Orbitec, Orbital Technologies Corp., PhytoFarms of America, Pierson Products, Inc., Silicon Sensors, Snap-On-Tools Corporation, Sundstrand Corporation, Sevrain-Tech, Inc., and the State of Wisconsin, Department of Development.

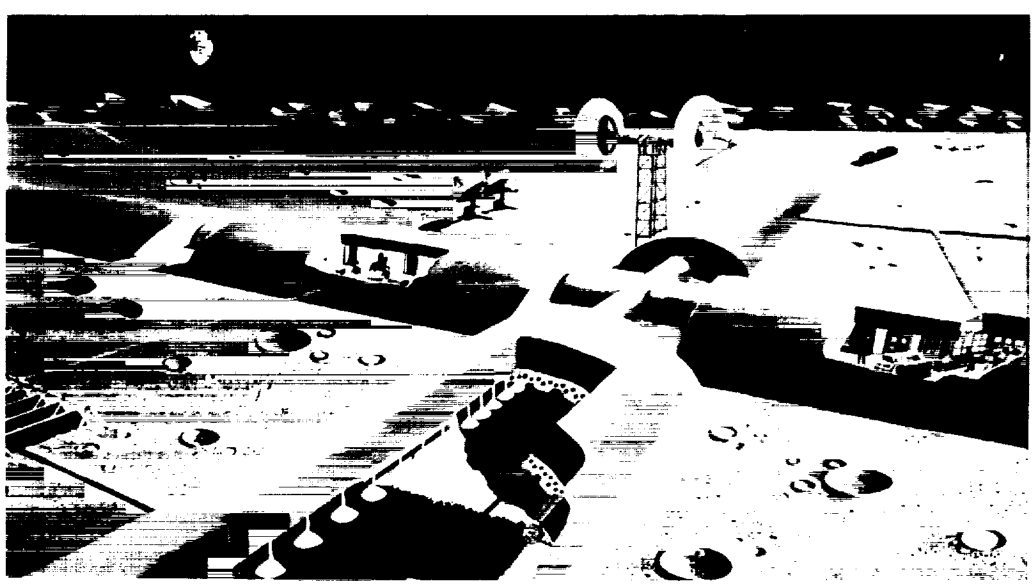
University participants are University of Wisconsin-Madison, University of Wisconsin-Milwaukee, Milwaukee School of Engineering, and Marquette University. □

For more information on the Wisconsin Center for Space Automation and Robotics contract:

Heidi Wilde
Program Coordinator,
Wisconsin Center for Space
Automation and Robotics
1357 University Avenue
Madison, WI 53715
(608) 262–5524

An artist's rendition is shown of a maneuvering anthropomorphic system functioning in both the autonomous and teleautonomous mode of a space station operation.

This conceptual illustration depicts a plant growth unit as a component of a lunar base.



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The Center for Autonomous And Man-Controlled Robotic and Sensing Systems

Investigations concerning the use of plant cell cultures as a resource for space exploration are aimed at developing Controlled Ecological Life-Support Systems for long-term space missions and extraterrestrial bases.

In April 1987, a team of leading academic, research, and private-sector institutions formed a consortium under NASA sponsorship to demonstrate the feasibility of commercial autonomous and tele-autonomous services in space. The Center for Autonomous and Man-Controlled Robotic and Sensing Systems (CAMRSS) promotes synergy among its participants and serves as a liaison between NASA, academia, and private industry.

Among the key technologies CAMRSS is developing to make space industrialization possible are machine vision and sensing systems, robotics and automated manufacturing systems, and biological technology for life-support systems.

CAMRSS is located in Ann Arbor, Michigan, a fast-growing, high-technology community with over 100 industrial research firms and government laboratories, and is housed at the Environmental Research Institute of Michigan (ERIM).

CAMRSS's research program supports existing CCDS activities in space-based materials processing and is coordinated with NASA's Space Station activities.

Current members include:

Ball Aerospace
Coulter Electronics
Environmental Research Institute of Michigan
Fairchild Space Company
Ford Aerospace
Geospectra Corporation
Grumman Corporation
Industrial Technology Institute
KMS Fusion, Inc.
Michigan State University
Michigan Strategic Fund
The University of Michigan

The center's two main research areas constitute missing links to long-term commercial space development. The first is automated construction, repair, and maintenance of orbital and remote planetary systems. Before space industrialization can become a reality, methods of maintaining the operational elements of remote systems must be determined.

The second activity concentrates on space-based biomass production, including biological systems for long-duration life support and automated biological processing.

CAMRSS's work requires developing tele-autonomous robots which are independent enough to function in variety of situations, yet are responsive to remote communication from a human operator. To support biomass production in space, new automation concepts in laboratory and life-support systems design must also be explored.

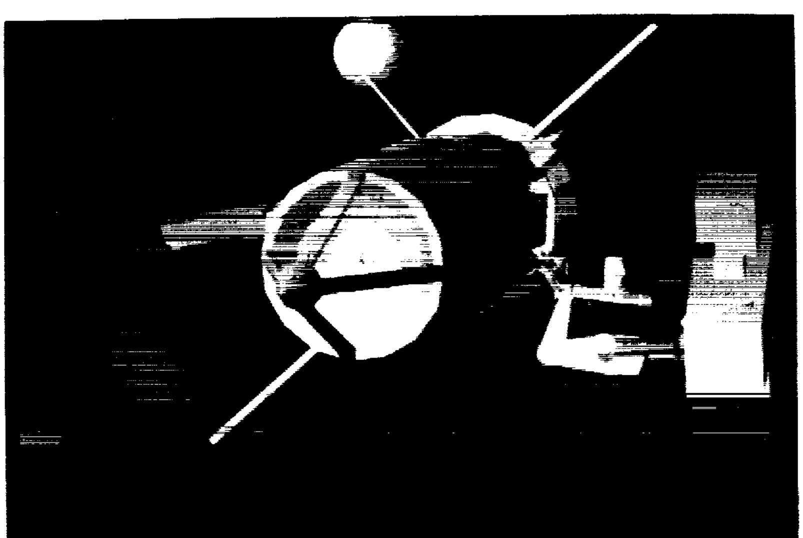
Another facet of CAMRSS's research effort is to define the market and marketing strategy for space servicing technology. To help ensure near-term profitability, each of the center's projects is linked to a clearly demonstrated terrestrial market.

CAMRSS also offers expertise to small businesses pursuing external funding opportunities. In Michigan, one-half of the most recent Small Business Innovation Research (SBIR) program recipients were supported by CAMRSS in preparing their SBIR proposal. □

For general information about CAMRSS, please contact ERIM, Public Communication at (313) 994–1200, ext. 3891.

For membership information, write or call:

Dr. Charles J. Jacobus
CAMRSS Director
ERIM
P.O. Box 8618
Ann Arbor, MI 48107
(313) 994–1200, ext. 2457 or 2738



Center researchers are exploring ways to automate space- and ground-based servicing technology as shown in this simulation of a satellite servicing system mock-up. An image understanding system coupled to robotics provides a symbolic description of the environment which can be manipulated by users.

Center for Advanced Space Propulsion

The Center for Aerospace Research, a not-for-profit venture of the University of Tennessee and Arvin/Calspan, established the Center for Advanced Space Propulsion (CASP) following award of a NASA grant in October 1987. CASP's mission is to initiate and conduct advanced propulsion research in partnership with industry.

Growth from five core projects conducted during the center's first year of operation to as many as 17 in the second, highlights CASP's acceptance as an emerging force in the commercial development of space propulsion technologies.

Located at the University of Tennessee Space Institute (UTSI) Research Park, the center is also near research and test facilities at the Air Force's Arnold Engineering Development Center, UTSI, and Marshall Space Flight Center. Investigators and research assistants are drawn from the University of Tennessee and Calspan's engineers and scientists.

CASP's first year experience has clearly established specific technical disciplines that represent the best match of what CASP can offer industry and what industry and NASA require. In chemical propulsion, CASP is concentrating on computational fluid dynamics analysis of rocket engine performance. In expert systems applications, the center is focusing on health monitoring and fault diagnosis, component life and assembly scheduling, fault pattern detection, and intelligent hypertext. With regard to low-gravity fluid dynamics, CASP is focusing on 2-phase fluid transfer and fluid management and control. In the area of electric propulsion, the emphasis is on development of a Magnetic Annular Arc (MAARC) thruster and an ion thruster.

CASP's industrial participants include Boeing Aerospace Company, Rocketdyne Corporation, Technion, Inc., Symbolics, Inc., Arvin/Calspan, TRW, Sundstrand, and Saturn Corporation. University participants include: University of Tennessee, University of Tennessee Space Institute, University of Alabama-Huntsville, and Auburn University. Marshall Space Flight Center and Lewis Research Center are also affiliated with CASP.

Representative projects include design, construction, and testing of a MAARC. In this project a nominal 25kw MAARC thruster using nitrogen, ammonia or hydrogen fuel will be produced for deep space mission, orbital transfer, and possibly station keeping.

CASP has also developed computational techniques for describing the inviscid flow field in the Space Shuttle Main Engine (SSME). These computer codes will be used to design high-area-ratio nozzles for future space propulsion systems.

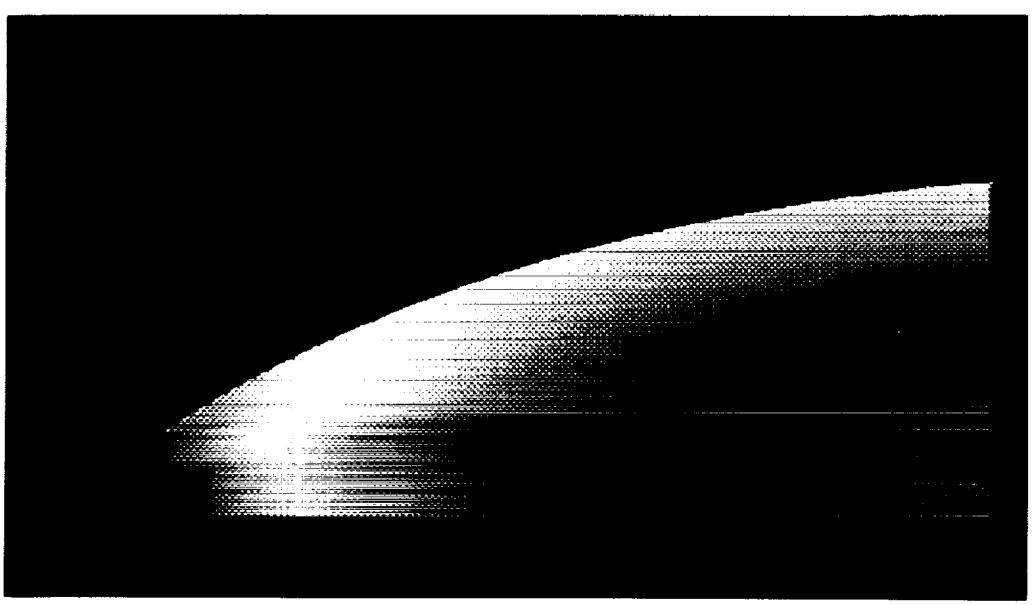
In addition, a SSME Component Assembly and Life Management System is being developed by CASP to assess the remaining life of all SSME components following each ground test or flight mission.

CASP is also examining liquid cryogen transfer and storage in low-gravity. In this project, the basic fluid and thermodynamic behavior involved in cryogen tank cooldown is being investigated with Boeing. □

For information on these and other projects of the Center for Advanced Space Propulsion contact:

Center for Advanced Space Propulsion
University of Tennessee Space Institute
P.O. Box 1385
Tullahoma, TN 37388–8897
(615) 454-9294

Center investigators review a display from artificial intelligence software.



The Space Shuttle Main Engine mach number contour levels shown are part of a CASP effort to develop computational techniques for describing the engine's flow field.

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Center for the Commercial Development of Space on Materials for Space Structures

The center's Low-voltage Scanning Electron Microscope is used to examine metals, ceramics, polymers, and composite materials directly without the application of coatings and is particularly useful for viewing fractured or damaged surfaces.

Established in September 1987, the Center for the Commercial Development of Space on Materials for Space Structures is a joint effort between Case Western Reserve University's (CWRU) Departments of Materials Science and Engineering and Macromolecular Science.

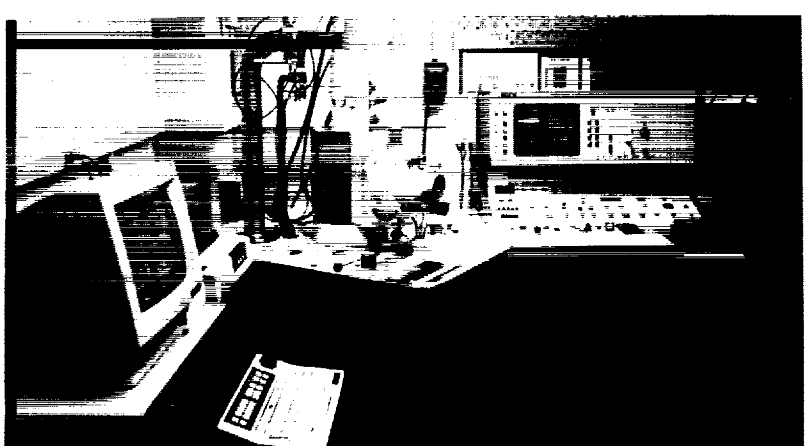
The goal of the center is to provide materials for space structures that are capable of being made and/or assembled in space and capable of withstanding the space environment. In addition to their direct use in space structures, these new materials will be developed commercially for Earth-bound applications.

Industrial participants of the center include the following companies: Dow Chemical Company, Dow Corning Company, Dural Aluminum Composites Corporation, Edison Polymer Innovation Corporation, Goodyear Tire and Rubber Company, TRW, Inc., and 3M. Each company is cooperating on several of the research projects being conducted in the different areas of materials for space stations.

NASA's Lewis and Langley Research Centers are also associated with the center.

Requirements identified as important for application of materials to large space structures include a life requirement of at least 30 years, in addition to resistance to environmental and mechanical attack in low-Earth orbit. Specific structural design issues include mechanical considerations, thermal fluctuations, space environmental effects, manufacturing processes, and cost.

The research areas cover the types of structures most likely to be used for research and long-term habitation in space. Thin films, used as the outer form in combination with plastic foamed materials as a filler, provide the basis for expandable solid structures with highly versatile internal/external shapes and a wide range of "design-in" characteristics.



The Thermal Fatigue Testing Unit can automatically cycle materials at a programmable rate and test materials that are up to seven inches long and one inch in diameter with temperatures ranging from 200°F to −150°F.

Lightweight, strong organic and inorganic composites are likely to be used as the building material for structural and load-bearing elements of large structures such as the Space Station.

Projects being undertaken include:

Coatings: Construction components will require protection from the space environment — particularly atomic oxygen and UV radiation. One project underway involves developing inorganic coatings that show resistance to these space environmental conditions.

Deformation Mechanisms of Continuous Organic Fiber-Reinforced Epoxies: Fiber-reinforced plastics have gained widespread use in aerospace applications mainly because of their extremely high specific moduli and strengths. Epoxies reinforced with strong, continuous organic fibers, such as graphite and Kevlar fibers, have been processed and tested.

LCP/PET Blends: Thermoplastics and thermoplastic composites are of interest to both the aerospace and aircraft industries due to weight and processing considerations. Thermotropic "self-reinforcing" liquid crystal polymers (LCP) blended with thermoplastic polyethyline terephthalate (PET) may yield a material with optimum properties. □

For more information on this center contact:

Center for Materials for Space Structures
Case Western Reserve University
School of Engineering
10900 Euclid Avenue
Cleveland, OH 44106
(216) 368–4222

Center for Commercial Development of Space Power

Future commercial activities in space will require power levels well above those currently available. Space power systems will have to be reliable, efficient, cost effective, fault tolerant, and possess a high degree of autonomy.

The Auburn Center for Commercial Development of Space Power was established October 1, 1987, with the objectives of identifying the critical technological impediments to the economic deployment of power systems in space, advancing these technologies, and developing new products to meet the power generation, storage, conditioning, and distribution needs of commercial space users. The center is administered by the Space Power Institute of Auburn University.

Lewis Research Center has been designated as the technical affiliate of the center. In addition, the Marshall Space Flight Center has agreed to provide close technical support.

The center maintains a partnership with its industrial members, with the partners providing valuable input on commercial opportunities, which is used to determine which research projects will be pursued. Industrial partners include AT&T Bell Laboratories, Maxwell Laboratories, Rocketdyne Division of Rockwell International, and Westinghouse R&D Center.

Other academic institutions affiliated with the center are Florida A&M University, University of South Carolina, University of Tennessee Space Institute, and State University of New York at Buffalo.

The center receives personnel support and the use — on a non-interference basis — of specialized facilities at the following: Lewis Research Center, Marshall Space Flight Center, Air Force Wright Aeronautical Laboratories, Hanford Engineering Development Laboratories, National Institute of Standards and Technology, and Sandia National Laboratory.

The center's research program is synergistic among several elements, each of which may be critical in a specific space power application.

These areas are:

- Power distribution, control, and management
- Discrete energy/power sources
- Advanced power system sensors
- Power conditioning
- Power transmission

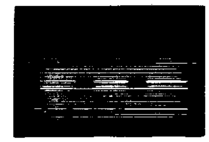
Each research project within the center offers the promise of commercial potential. At the same time, complete systems are required for space power applications. This necessitates integration of all research areas in the program. The result is an overall technology focus, which is outlined in Figure 1.

The current research program underway will provide the basis for developing complete power system packages, tailored to specific user needs.

An example of the work underway deals with the design and fabrication of power conversion equipment. This project involves the investigation of candidate circuit topologies for specific applications to determine their impact on issues such as weight, efficiency, component stress, and reliability. □

For more information on the Center for the Commercial Development of Space Power contact:

Dr. Raymond Askew
Space Power Institute
Auburn University
Auburn, AL 36849–5320
(205) 844–5894



A new commercial line of capacitor charging power supplies resulted as a spinoff of new technology developed from CCDS power research.

Scientists conduct research in the Space Power Institute hypervelocity launch facility and space environmental test chamber.

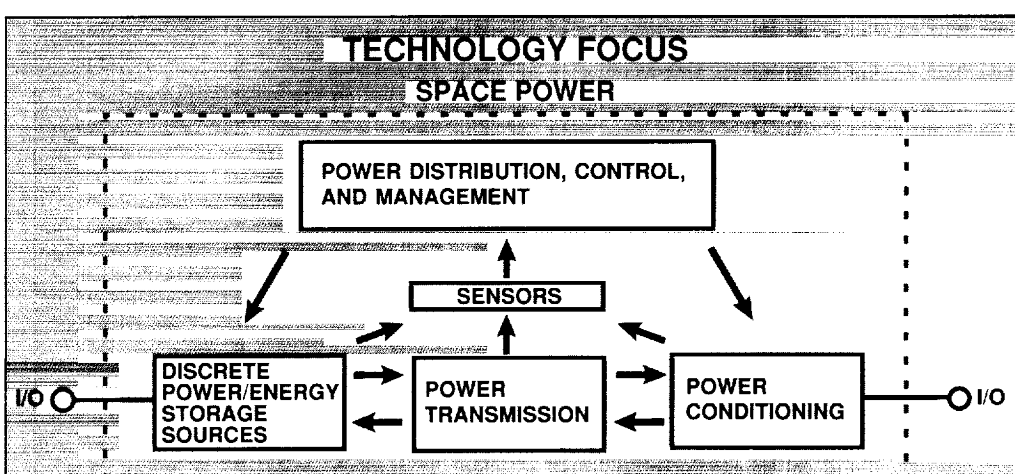


Figure 1

Center for Space Power

Space Stations, unmanned platforms, and lunar bases represent just a sampling of current space programs planned for the future. With these developments nearing reality, a key factor in their success is the readiness of power systems to support pioneering efforts and permanent habitation in space.

The Center for Space Power at College Station, Texas, is at the forefront of power systems research. The center's goal is to demonstrate in the next five years that providing power in space is indeed a viable commercial activity.

Center activities involve collaboration of researchers and engineers from university and corporate entities working to develop critical space power technologies. A systematic approach starting with market studies and technology assessments is being followed by specific research and development tasks on materials, components, systems, and services essential to space power.

Established by NASA in 1987, the Center for Space Power is operated as a unit of the Texas Engineering Experiment Station, a state agency dedicated to promoting research and high technology.

The Center for Space Power provides these services:

- Identifies and conducts research to enhance space power systems technologies;
- Brings together expertise and excellence among interdisciplinary researchers for the analysis, design, fabrication, and operation of space power systems;
- Facilitates technology interchanges between companies and universities through cofunded projects;
- Enhances education programs for the training of space technology professionals;
- Sponsors symposia and similar activities;
- Assists companies in recruiting qualified students for employment and research studies; and
- Promotes communication among researchers, NASA, other agencies, and industry.

Other benefits to participants include the following:

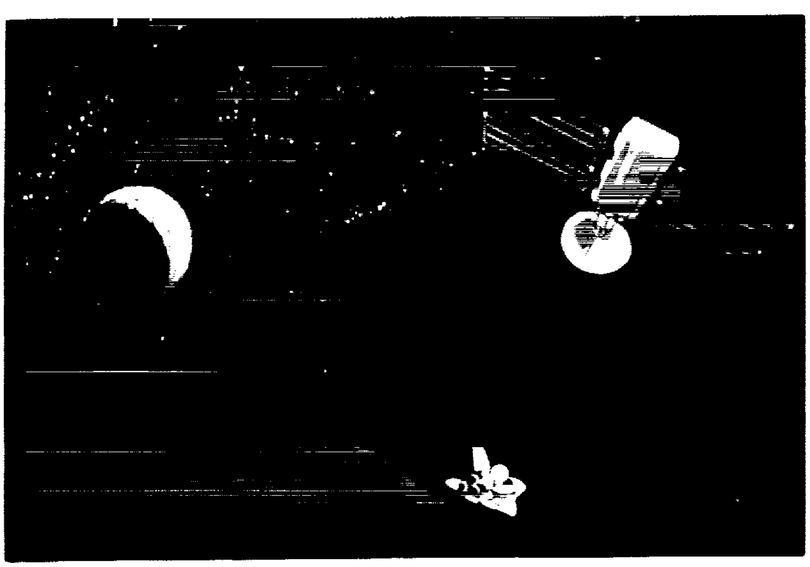
- Providing financial leverage by maximizing research and development investments through cofunding;
- Accelerating development of space-related commercial products;
- Training personnel by providing unique opportunities for research and continued technical education;
- Facilitating access to space flight opportunities;
- Developing contacts between industry and academia; and
- Expanding commercial opportunities and markets in space.

Research interests include power systems for individually designed applications — such as a communication satellite or Space Shuttle — and for future needs such as Space Stations, man-tended free fliers, lunar bases, and other powered installations.

Short-term projects include improving individual components currently used in space power systems, such as batteries, fuel cells, solar panels, and power conditioning. Long-term projects address the development of new power systems using photovoltaics, solar dynamics, and nuclear systems for power production — or a combination — with power distribution through hardwiring or microwave/laser transmission. □

For more information on the Center for Space Power contact:

Center for Space Power
Texas Engineering
Experimentation Station
The Texas A&M
University System
College Station, TX
77843–3118
(409) 845–8768



An artist's rendition of microwave power transmission illustrates one of the major projects being conducted by the Center for Space Power.